$AC$

**(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)**

(72) Inventors; and
(75) Inventors/Applicants (for US only): HORNEMAN, Kari [FI/FI]; Kaijantie 36, FIN-90800 Oulu (FI). KEISALA, Jyrki [FI/FI]; Tellervontie 3 C 25, FIN-90570 Oulu (FI).

**(54) Title: DETERMINATION OF DATA RATE, BASED ON POWER SPECTRAL DENSITY ESTIMATES**



calculate PSD from these 64 received symbols · calculate PSD from these 64 received symbols · calculate PSD from these 64 received symbols · · · calculate PSD from these 64 received symbols

32 values in PSD · 32 values in PSD · 32 values in PSD · · · 32 values in PSD

coherent averaging of 160 PSDs

bias = 1/32

remove the bias and reset negative values

$y(i)$

calculate the Center-of-Moment (CM)

$$cm = \frac{\sum_{i=0}^{31} i \cdot y(i)}{\sum_{i=0}^{31} y(i)}$$

decide transmission bit rate based on $cm$

(57) Abstract: The present invention relates to a method and a circuitry for estimating data transmission rate in a communication system. The communication system utilises variable data transmission rates. A transmission signal between two stations of the system includes a plurality of data symbols over a sequence of data frames. A data frame of a received transmission signal is classified in accordance with a predefined classification of the data transmission rates, whereafter the data transmission rate of the received data frame is estimated on basis of said classification.

WO 01/19043 A1

# DETERMINATION OF DATA RATE, BASED ON POWER SPECTRAL DENSITY ESTIMATES

**Field of the invention**

5    The present invention relates to a method and circuitry for
estimating data rates of signals transmitted between stations
in a communication system, and more particularly, but not
explicitly, between stations in a cellular code division
multiple access (CDMA) communication system.

10

**Background of the Invention**

In a communication system signals can be transmitted with
variable data transmission rates wherein data is transmitted
as a plurality of data symbols in subsequent data frames. As
15   is known, in a cellular CDMA (Code Division Multiple Access)
system data is encoded for transmission by modulating data
symbols to be transmitted by a spreading code and a unique
scrambling code for each channel. Within each cell of the
cellular communication system, scrambling codes are
20   preferably as far as possible orthogonal to allow for a
plurality of different mobile stations to communicate with a
base station on selectively coded channels. The effect of a
spreading code is to spread the frequency band for
transmission to a chip rate Tc which is larger than the bit
25   rate $T_b$. The scrambling code is unique for each mobile station
transmitting to a single base station so that the
transmission from individual mobile stations can be
distinguished at the base station. The spreading codes are
also as orthogonal as possible within users. For example, it
30   is possible to set up such a variable-rate connection where
the data rate of the information bits, and thus the spreading
factor used in the spreading modulation of these bits, varies
from radio frame to radio frame (e.g. every 10 ms). The data

rates used in such a connection are not arbitrary, but for each radio frame duration, one of the pre-defined data rates is used. Moreover, every higher data rate is dividable by a lower data rate, the division factor being $2^k$ for some $k \geq 0$.

5    This specification presents variable-rate connection data rates 32, 64, 128, 256, 512, and 1024 kbps, but it is evident that also other data rates could be used without departing from the basic concept of the variable data rate (or multirate) transmission.

10

When a signal is transmitted between a base station and a mobile station (either on the uplink or the downlink) of a CDMA system, the signal receiving unit needs to establish from the received signal some information about the

15    communication path along which the signal has travelled. This is referred to herein as "channel estimation" and is usually carried out in a channel estimation unit which generates a channel impulse response. Various techniques are known for channel estimation. The channel impulse response is

20    required in order to properly decode and demodulate incoming data.

The data transmission rate of the received signal can be used in the channel estimation. However, if the data rate of a

25    received radio frame is not known at the time of the detection at the receiver, the information symbols in said radio frame are usually obtained by means of detecting the complex data symbols assuming that the highest-possible data rate is used for transmission, and using the lowest-possible

30    spreading factor in the receiving station. Assuming that the data rate of the received radio frame was 1024 kbps, this corresponds to the spreading factor of 4 (at 4.096 Mcps) used in the detection of the data symbols. The result of this detection should be a data vector of all detected complex

information symbols corresponding to the received radio frame. Thereafter it has to be estimated what was the actual data rate of the signal at the transmitting station during the transmission. For example, this stage might give a

5 decision that the actual data rate in the received radio frame was 256 kbps, not the assumed 1024 kbps. Finally, in accordance with the estimated data rate, as many adjacent symbols as necessary are summed together to get one actual information symbol. In this example, this would lead to

10 summing up every four adjacent symbols to get one actual information symbol. Therefore it would be advantageous to be able to have the actual data rate of the transmission at the time of the detection at the receiver circuitry.

15 The transmission between the stations may or may not include explicit information of the data rates of the transmitted signal. In the first case, i.e. if the variable-rate connection includes explicit information on the used data rates for each received radio frame, this information is

20 usually given in a separate channel, for example in an DPCCH (Dedicated Physical Control Channel). However, this information is often encoded in such a way that the actual data rate of the received radio frame is not known at the time the data symbols of the radio frame are detected. In

25 addition, it may be necessary to establish another estimate of the data rate, for instance for the purposes of verification and/or correction of the received data rate information. In the latter case, i.e. if the explicit information is not included in the received signal, so called

30 unknown or blind data rate estimation may be used at the receiving station in order to define at the receiver the actual data rate of the received signal.

One prior art proposal for detecting the data rate of the

received signal is based on the power difference of the
received bits in the data channel and the control channel.
This method is relatively simple as it requires only the
average power estimates of the received control symbols and
data symbols. However, the disadvantage of the method is that
if a very low spreading factor is used in detecting the data
symbols (4 in the above example) in the first place noise
becomes very dominant in the detection process. This degrades
substantially the performance of the data symbol power
estimation.

Another prior art method is based on CRC (Cyclic Redundancy
Check: an error detection signal) decoding of the received
signal. The method is based on a data rate assumption at each
decoding stage and a subsequent selection of a data rate
which gives a correct CRC word. To give an example, assuming
that the possible data rates are 32, 64, 128, 256, 512, and
1024 kbps, a CRC check would be calculated directly for the
information symbols of the received radio frame by assuming
firstly a data rate of 1024 kbps. The resulting CRC word is
stored. Two adjacent received symbols are summed together,
assuming a data rate of 512 kbps, and a further CRC check is
calculated for these information symbols. The resulting CRC
word is stored. The process continues summing two adjacent
information symbols together and calculating CRC checks for
all these information streams until a lowest-possible data
rate is achieved. Thereafter the stored CRC words are
verified and such a data rate is selected that corresponds
the rate used in the transmitter when a right CRC check was
obtained (if such existed at all). A disadvantage of this
method is that it is computationally complex: if there are $N$
possible data rates, this requires N consequent CRC decoding
processes before a decision of the transmitter data rate can
be made. Moreover, the method does not give any data rate if

the algorithm does not give an exactly matching CRC check.

One prior art proposal is based on metrics of Viterbi decoding of the data, assuming (as in the CRC method) a

5      certain data rate at each stage of the decoding process. This method, however, is also computationally complex and uses assumptions which may lead to even more complicated arithmetical operations and/or inaccurate results of the estimation procedure.

10

An additional disadvantage of the two latter prior art methods is that they delay the final decision of the data rate of the received signal to a stage where some decoding of the data is needed for the first time. This will make the

15     operation difficult for receiver structures that require an estimate of the data transmission rates of the received signals at an earlier stage than decoding. One such receiver comprises an Interference Cancellation (IC) receiver.

20     **Summary of the Invention**

It is an aim of the embodiments of the present invention to address one or several of the disadvantages of the prior art data rate estimation and/or to provide a new type of solution

25     for data rate estimation.

According to an aspect of the present invention there is provided a method for estimating data transmission rate in a communication system with variable data transmission rates

30     wherein a transmission signal includes a plurality of data symbols over a sequence of data frames, the method comprising steps of classifying a data frame of a received transmission signal in accordance with a predefined classification of the data transmission rates and estimating the data transmission

rate of the received data frame on basis of said
classification.

According to a more specific embodiment, the classification
5    is based on frequency content of the received transmission
signal. The classification can be based on a power spectral
density function estimate of the received transmission
signal. The power spectral density function estimate can be
calculated using a Fast Fourier Transform algorithm and
10   coherent averaging of the data symbol sequence of the
received transmission signal.

The power spectral density function estimate can also be
normalised by summing the elements of the power spectral
15   density function for obtaining a sum of the elements and by
dividing each of said elements by the sum.

Effect of noise can be removed by subtracting an inverse of
the number of elements of the power spectral density function
20   from the power spectral density function.

The classification can comprise further steps of calculating
a variable from the power spectral density function for
characterising the frequency content of the power spectral
25   density function, and comparing the variable against limit
values of a classification decision structure.

The estimated data transmission rate can be used in channel
estimation.
30

According to another aspect of the present invention there is
provided a signal receiving circuitry for use in a
communication system with variable data transmission rates
wherein data is transmitted as a plurality of data symbols

over a sequence of data frames, the signal receiving
circuitry comprising a rate estimation unit for receiving an
incoming transmission signal, for classifying a data frame of
the signal in accordance with a predefined classification of
5   the data transmission rates, and for determining from the
results of the classification an estimate of the data
transmission rate of the received data frame.

According to a more specific embodiment, the signal receiving
10  circuitry is included in a mobile station and/or a base
station of a cellular communication system.

The embodiments of the present invention provide several
advantages. The embodiments of the invention can be used in a
15  situation where no rate information is transmitted. In
addition, the embodiments of the invention can be used in a
situation where the rate information is transmitted but
cannot, for reason or another, be used or detected from the
signal during the receiving process. In addition, one
20  possible use is to provide an additional data rate
information which can be used e.g. for correction or error
check of a rate information detected from the transmitted
signal. The estimate of data transmission rate can also be
used in other parts of the received signal processing
25  sequence, e.g. in an IC receiver. The possibility for an
early detection of the unknown data rate enables use of any
such receiver structure which makes use of the data rate
information at an early stage. The estimate can also be used
to assist in rate selection for Viterbi decoding of the
30  incoming data symbols, or to assist in decision of an
alternative transmission rate for decoding if an error check
fails. In addition, embodiments of the invention may assist
in provision of a system that is less sensitive to SNR
(Signal-to-Noise Ratio) fluctuation.

## Brief Description of Drawings

For a better understanding of the invention and to show how
5    the same may be carried into effect reference will now be
made by way of example to the accompanying drawings in which:
Figure 1 is a block diagram of a mobile communication
system;
Figure 2 illustrates a reception circuitry in a station;
10    Figure 3 illustrates a slot structure for physical
channels for a transmission with unknown data rate;
Figure 4 illustrates a blind rate classification
algorithm according to one embodiment of the invention; and
Figure 5 is a diagram showing simulated distributions of
15    variables for different data rates.

## Description of Preferred Embodiments of the Invention

Figure 1 is a block diagram illustrating a context in which
20    the present invention may be used. That is, a CDMA mobile
communication system allows a plurality of mobile stations
MS1, MS2, MS3 to communicate with a base (transceiver)
station BTS in a common cell via respective channels CH1,
CH2, CH3. These channels are distinguished from one another
25    by the use of scrambling codes in a manner which is know per
se. Figure 2 is a block diagram of a receive circuitry at a
base station in a WCDMA system (Wideband CDMA). The receive
circuitry of Figure 2 is for use in uplink direction, i.e.
for receiving signals from the mobile stations (MS). It is
30    noted that even though the actual receive circuitry
implementation in the downlink direction, i.e. at the mobile
station, can be somewhat different, the invention is
applicable to downlink transmissions as well.

Before describing the exemplifying receiving circuitry of Figure 2 in more detail, a transmit circuitry (not shown) within a transmitting station will be briefly described. Data to be transmitted between a MS and a BTS may be speech data,

5  video data or other data. The data is encoded into a form suitable for transmission at a bit rate $T_b$ which is dependent on the source of the data, as discussed above. The encoded user data is supplied to a frame multiplexer. The user data can also be supplied to a CRC encoder which generates a check

10  sequence (CRC) for each frame of data. Error correction coding and bit interleaving of the frame sequence can be accomplished prior to transmission in a manner known in the art. The error correction is used in order to protect the user data from errors in a radio channel so that e.g. a

15  Viterbi decoder can recover the coded data even if some of the bits are corrupted. For error coding and decoding purposes, tail bits defining the end of each user data sequence can also be added to the end of user data sequence. Bit interleaving spreads burst errors which typically occur

20  in radio channels more evenly in time to allow the decoder to more efficiently correct the errors from the coded data.

A frame multiplexer organises the data for transmission into a frame sequence. Figure 3 illustrates an example of a slot

25  structure for physical channels DPCCH (Dedicated Physical Control Channel) and DPDCH (Dedicated Physical Data Channel) in the frame sequence. The DPCCH part of the frame contains a pilot sequence (PILOT), a possible rate information (RI) sequence (not shown) and a transmission power control (TPC)

30  sequence. The DPDCH part of the frame contains the whole interleaved user data sequence (user bits and possible CRC bits and possible tail bits). Typically, the user data of the DPDCH is divided into frame periods of 10 milliseconds each, and each frame can have a different transmission rate. Thus,

it is possible to multiplex data from different sources into
the frame sequence for transmission and to provide different
transmission rates in different frames of the frame sequence.
In the following exemplifying embodiments the data rate
5   detection is subjected to the DPDCH sequence of the frame.

The frame sequence is supplied to a spreader which receives
spreading and scrambling codes from a code generator.  The
spreading and scrambling codes are generated in accordance
10  with known CDMA techniques and will not be described further
herein. The effect of the spreading code is to spread the
frequency band for transmission to a chip rate Tc which is
larger than the bit rate $T_b$.  As explained, the scrambling
code is unique for each mobile station transmitting to a
15  single base station so that the transmission from individual
mobile stations can be distinguished at the base station. If
M parallel code channels are employed, M data symbols are
spread using different codes and then the results are summed
together. The spread signal is supplied to a modulator which
20  modulates the signal ready for transmission, for example
according to QPSK modulation. In some systems, modulation is
carried out prior to spreading. This sequence of events,
however, has no impact on the present invention. The spread,
modulated signal is supplied to a digital to analogue (D/A)
25  converter and from there to an RF unit which supplies the
signal ready for transmission.

The reception side of the uplink connection will now be
described with reference to Figure 2. Signals incoming at an
30  antenna 30 are received by an RF unit 28 and supplied to an
analogue to digital (A/D) converter 32. It will readily be
understood that a signal may arrive at the receiving station
having experienced multipaths with differing propagation
delays dn. The A/D converter 32 supplies the digital input

signal to a synchronisation unit 34, a channel estimation unit 37 and to each of a number of despreaders 36a, 36b, 36c. The number of despreaders depends on the likely number of paths experienced by the signal from the base station to the mobile station and is thus dependent on the environment. The synchronisation unit 34 handles the synchronisation of the mobile station to the base station BTS after power has been turned on as well as in a handover case. This includes searching for signals which have been transmitted with the unique scrambling code for that mobile station. Thus, the synchronisation unit 34 receives the unique code from the code generator 22. To perform the search function, synchronisation unit utilises the unique code from the code generator 22 and correlates it with the incoming signal until a strong correlation is detected. After the synchronisation procedure is completed, a dedicated traffic channel can be established. An impulse response measurement unit 35 deals with estimation of the propagation delays dn in order to be able to provide each despreader 36a, 36b, 36c with required scrambling code phases Ø. The phase value of the strongest correlation is supplied to the first despreader 36a and the process is continued to supply respective phase values Ø to the remaining despreaders 36b and 36c. Respective code generators within the despreaders 36a to 36c can thus be used to despread the signal in accordance with the determined phase difference and the resulting narrowband signals are supplied to a coherent combiner and demodulator unit 38.

A channel phase estimate from the channel estimation unit 37 is needed for the combining and demodulation process of the data symbols. Furthermore, an estimate of the data rate is needed from a rate estimator 40 in order to be able to decide how many successful data symbols are to be summed together.

The combined demodulated signal is supplied to a bit
detection unit (not shown) which makes a soft or hard
decision on the received symbols as to the transmitted bits.
The detected bit sequence from the bit detection unit is

5    supplied to a deinterleaving unit (not shown) which
effectively undoes the action of the interleaver of the
transmitter. The deinterleaved signal can be supplied further
to a decoder (not shown) which decodes the error correction
coded bits back to the sent user bits and possible CRC bits.

10

It is noted that several alternative circuit structures to
the embodiment shown in Figure 2 are possible to implement
the embodiments of the present invention. However, it is
generally advisable to have the rate estimation carried out

15   as soon as possible in the receiving process so that it does
not hold up the data rate estimation for longer than is
necessary.

As already briefly mentioned above, the circuit is provided

20   with the rate estimator unit 40 arranged to receive the
despread signal from the despreader 36a. The signal from
despreader 36a is assumed to be the strongest signal (i.e.
that which has come in along the primary path). As shown by
the dashed lines between the signals (branches) from the

25   despreaders 36b and 36c, it is also possible to supply
information from a plurality of the despreaders to the rate
estimator. According to an option (not shown) more than one
estimator 40 is provided in the circuitry. If a plurality of
estimators is used, each of the estimators may estimate the

30   data rate of a single signal output branch from despreaders
36a to 36c. Two or several signal branches may also be
combined prior to estimation in one of the several
estimators, e.g. such that the one estimator estimates the
strongest signal while a second estimator estimates the two

next strongest paths and so on.

The rate estimator 40 estimates the data transmission rate by examining the structure of the despread data. The following will describe an embodiment for estimating the transmission data rate of subsequent frames by classifying the data rate of a received signal at the estimator 40 into one of predefined categories, whereafter the decision of the actual data rate of the received signal is based on the predefined category.

The classification of the received signal can be accomplished by examining the frequency content of the received signal, e.g. by means of an estimated one-sided Power Spectral Density (PSD) function of the received signal, as is shown in Figure 4. This is based on the realization that an $N$-point PSD function of the signal can be defined for an $N$-point complex time domain signal, said function providing information about the frequency content of the signal. A crude estimate of the PSD function for a signal $x$ can be calculated from a Fourier Transform (FT) of the signal $x$ by equation:

(1)   $PSD(x) = Re(FT(x)) * Re(FT(x)) + Im(FT(x)) * Im(FT(x))$

The PSD function includes $N$ real values, and the relative amplitudes of these values can be translated to the relative amount of different frequencies present in the signal, starting from the frequency $f = 0$ as the first element of the PSD function and spanning a frequency range up to the Nyquist critical frecuency

(2)    $f_c = \dfrac{1}{2T_s}$ ,

where $T_s$ = symbol time of one received symbol, despread by
using a spreading factor of 4. Now, as one 10 ms radio frame
includes 16 * 10 * 64 = 10240 such symbols, the symbol time
is:

$$T_s = 10 \text{ ms} / 10240 = 0.977 \ \mu\text{s}$$

and thus        $f_c = \dfrac{1}{2 \cdot 0.977 \,\mu\text{s}} = 512$  kHz.

The above corresponds to a data rate of 512 kbps, which means
that in this embodiment, i.e. with a sampling rate of 0.977
$\mu$s (using a spreading factor of 4) it is not possible to
separate data rates over 512 kbps in the PSD function. This
is caused by the nature of the Fourier transform algorithm,
i.e. two samples for each transmitted symbol are required in
the receiver in order to be able to distinguish by a Fourier
transform a certain data rate (frequency). Since the data
rate 1024 kbps means that a spreading factor of 4 is used in
the transmitter, a spreading factor of 2 should then be used
in the receiver to get 2 samples of each transmitted data
symbol.

In general, having only $f_c = 512$ kHz means that in the highest
data rate case the frequencies over 512 kHz are aliased to
the PSD function, that is, they are mapped somewhere between
0 and 512 kHz. However, this does not have any
disadvantageous effect to the embodiment, since it is not
necessary to analyze directly the frequency content of the
signal (that is, the relative amplitudes of the PSD
function). Instead, the aim of this procedure is to interpret

the frequency content of the signal so that a single decision variable for classification purposes is obtained. Examples of the calculations for receiving the variable will be explained later in this specification.

5

To estimate the PSD of the received 10240 real symbols of one radio frame, it is possible to accomplish the estimation procedure directly by calculating the Fourier transform of all 10240 symbols and to subsequently calculate from the

10 Fourier transform a PSD estimate. This basic PSD method is enough for enabling an implementation of the above method. However, a preferred procedure discussed in the following will yield to even better results.

15 When the total number of received symbols $P = 10240$, the $P$ symbols are divided to $K$ blocks of $N$ consecutive points in each block. In this example $N = 64$, so $K = P / N = 160$. $N/2$-point FT is then calculated to each block of N real symbols separately. Denoting $M = N / 2$ yields to M (=32)

20 complex values per each FT. The M-point real PSD function estimate can then be calculated to each data block by summing the squared real and imaginary points for each frequency (see equation (1)). Finally, the final PSD function estimate is calculated by averaging these $K$ individual PSD function

25 estimates.

This procedure has been found to reduce the variance of the PSD function estimate by a factor of $\sqrt{K}$ (= 12.65) from the basic PSD method. The latter method is also in most cases

30 computationally more efficient, since the Fourier transforms of the signal are usually calculated with some kind of Fast Fourier transform (FFT) algorithm, and those algorithms are generally $\log_2(N)$-complex. Thus, even though both method can

be used, it is in most cases logarithmically more efficient
to use several short FFTs than to use one long FT.

Computationally, the biggest burden of the above method lies
5    in calculating the 32-point complex Fourier transform to the
64 real symbols of a certain block. However, the complexity
of the algorithm can be significantly reduced by using a
clever FFT algorithm, preferably one that has been especially
modified to take into account certain symmetries concerning
10   the FTs of real data. Such algorithms are per se known, and
are thus not discussed in more detail herein.

In pseudo-code representation, the estimation of the PSD
function can be written now as:
15

```
        divide input data to K blocks, N consecutive data
        symbols in each block;
        M = N / 2;
        for i := 1 to K
20              x := all N real data symbols belonging block i;
                /* The M = N / 2 real points of the FFT are
                returned to fx, and the imaginary points to fy */
                FFT_REAL(x, N, fx, fy);
                for j := 1 to M
25                      psd(j):=psd(j)+[fx(j)*fx(j)+fy(j)*fy(j)];
                end for j
        end for i
        divide all elements of psd() by K;
```

30   After the K M-point PSD functions have been averaged to one
M-point PSD function estimate, it may be advantageous to
normalise the estimate so that the total power of the PSD
function is 1. The normalisation is done by summing all the M

elements of the psd() and dividing all elements by this sum. By means of this the sum of the elements of the PSD function, called as PSD *bins*, is 1.

5   When considering Additive White Gaussian Noise (AWGN) of the signal, one of its properties is that it is white, i.e. non-selective. In other words, the noise extends equally to all frequencies. From the point of view of the PSD function, this would mean that the PSD function of the AWGN would be just a

10   flat line with the value of each bin = $1/M$. For a signal of distinct frequencies of $0...f_c$ plus the AWGN noise in the signal, the PSD function would thus show a bias of $1/M$, and for the distinct frequencies the corresponding bin of the PSD function would be greater than $1/M$. Since the proposed

15   estimation method is only interested of the frequencies whose relative amount in the PSD function exceeds the noise, $1/M$ can be subtracted from the PSD function and all possible resulting negative bins can be reset to zero.

20   In pseudo-code representation, the normalisation and bias removal operations can be written as

```
NORMALISE(psd, M);
for i := 1 to M
        psd(i) := psd(i) - 1 / M;
        if psd(i) < 0
                psd(i) := 0;
        end if
end for i
```

25

30

Before the actual classification of the incoming signal, a final data rate decision variable has to be calculated. As mentioned above, the shape of the PSD function gives

information about its frequency content. It has been realized
that for a transmission of lower data rates, e.g. 32 kbps,
the PSD function of the received signal is concentrated more
to the lower bins, whereas for a transmission of higher data

5   rates, e.g. 1024 kbps, much higher frequencies are present in
the signal. Thus the relative amount of the higher bins
present in the PSD function has to be bigger. In order to be
able to utilize this realization, a variable characterising
the frequency content of the PSD function is calculated. A

10  possible variable for this is so called center-of-moment (CM)
of the PSD function:

$$(3) \quad CM = \frac{\sum_{i=1}^{M} i \cdot psd(i)}{\sum_{i=1}^{M} psd(i)}$$

15  The meaning of the CM variable is as follows: the bigger the
CM, the bigger the relative amount of the higher frequencies
that are present in the PSD function, and thus it is more
probable that the transmitter bit rate was relatively high.

20  The above algorithm has been tested by extensive simulations
accomplished by a MATLAB simulation software provided by *The
MathWorks Inc*. The distributions of the PSD center-of-moment
variable for various transmission data rates are illustrated
in Figure 5 by a histogram in which the horizontal axis

25  defines the number of the PSD bins and the vertical axis
defines the number of events. The number of events axis could
also be presented in the normalised form, i.e. 0 to 1 instead
of the range from 0 to 2200. The distribution curves for
different data rates are from left to right: 32, 64, 128,

30  256, 512, and 1024 kbps. As can be seen from Figure 5, the
higher data or bit rates (256 and above) are very clearly

distinguished from each other, which leads to a reliable
detection of the higher bit rates.

It is possible to define the distribution of the CM variables
for all used (and thus possible) transmitter data rates (32,
64, 128, 256, 512, and 1024 kbps in the example). Based on
the predefined distributions, it is then possible to set
classification limits for the actual data rate decision. The
transmitter data rate estimate can thus be provided by means
of the CM variable calculation, followed by a classification
of the variable in accordance with a predefined
classification rules, e.g. by an estimation structure making
use of the predefined classification limits. The actual data
rate can then be defined directly from the class.

One possible decision structure for the final estimation is
shown below in pseudo-code representation, wherein $sf$ =
estimate of the spreading factor used in the transmitter:

```
CALC_CM(psd, M, cm);
if cm < 1.8
     sf := 128;
else if cm >= 1.8 and cm < 2.5
     sf := 64;
else if cm >= 2.5 and cm < 3.7
     sf := 32;
else if cm >= 3.7 and cm < 5.5
     sf := 16;
else if cm >= 5.5 and cm < 8.6
     sf := 8;
else if cm > 8.6
     sf := 4;
end if
```

The above structure has shown reasonable performance in the
accomplished simulations. It is noted that the above decision
limits are only tentative. In addition, the above illustrated
number of data transmission rate classes is only one example
of the possible number of classes. Different limit values can
be used in different embodiments, and the number of data
transmission rate classes can be freely chosen for different
implementations.

It is also noted that even though in a preferred embodiment
the number of the data rate classes corresponds the number of
the possible transmitter data rates, the number of the
classes does not necessarily need to correspond the number of
the different possible transmitter data rates. For instance,
a lower number of classes can be used such that two or
several of the lower transmitter data rates are included in
one data rate class, thereby simplifying the classification
procedure and avoiding possible problems caused by the
occasionally interleaving distributions of the variables for
the lower data rates. In addition, instead of using the
actual data rates, the data rate classes can also be denoted
as, for example, low, relatively low, medium, relatively
high, and high and such that some or all of the classes
include more than one transmitter data rate.

The accomplished simulations proved that the above embodiment
does not seem to suffer from the low signal-to-noise ratios,
as is the case in the prior art power-based method discussed
earlier in this specification. The simulations were done with
the $E_s/N_0 = 10$ dB, where the power-based method failed to
detect any data rates of the received transmission. At this
$E_s/N_0$ magnitude the above described embodiment, however,
achieved the following probabilities of correct data rate

detection (the simulation was accomplished for 10000 radio frames):

| Transmitter data rate [kbps] | Probability of correct data rate detection [%] |
|---|---|
| 32 | 46.85 |
| 64 | 92.25 |
| 128 | 100 |
| 256 | 100 |
| 512 | 100 |
| 1024 | 100 |

5   When compared to the described prior art methods based on the
CRC decoding and the metrics of the Viterbi decoding, the
above embodiment has an advantage in that the data rate
estimation is not delayed to after the decoding process.
Therefore the embodiment is more suitable to e.g. different
10  Interference Cancellation methods in the receiver that the
prior art proposals. Moreover, the above described method is
less complex than the methods based on CRC or Viterbi
decoding of the data.

15  As can be seen from Figure 5 and the above table, the
described embodiment may not reliably separate in all
occasions the lowest data rates of 32 and 64 kbps from each
other. This is due the fact that every higher data rate is an
integer multiple of two of a lower data rate, the data rates
20  32 and 64 kbps being relatively close to one another. Because
of that, the distributions of the decision variable (CM) may
overlap. If the incorporation of the lower data rates into
one class is not desired and a better performance in the
separation of the lowest data rates is required (at the cost
25  of the separation of the higher data rates), the sampling
rate of the receiver could be decreased, for example, by

increasing the spreading factor from 4 to 16 in the receiver. If the length of the Fourier transform is kept the same (e.g. 64), this would lead to decrease in the critical Nyquist frequency $f_c$, thus improving the frequency resolution at the
5    lower frequencies while at the same time narrowing the window of the detectable frequencies. It is to be noted that this process may in some occasions lead to heavy aliasing to the frequencies higher than $f_c$, if they are still present in the system (i.e. there is a probability that e.g. 1024 kbps might
10   still be used in the transmitter). This aliasing effect, however, can be readily reduced by using low-pass filtering to the received signal prior to the data rate detection.

Although the invention has been described in the context of a
15   CDMA based system, it will be appreciated that similar principles can be applied in other communication systems, for example in a TDMA system or in any telecommunications device receiving data at variable rates and requiring information of the data transmission rate, such as in modems.
20

While the invention has been described above in connection with the blind data rate detection, the described data rate estimation method could be used together with rate information bits or similar data rate information in order to
25   produce verified and/or corrected data rate estimate. In this case a connection is to be provided between rate estimator unit 40 and channel estimation unit 37 or similar unit of the circuitry accomplishing the verification/correction. This is a viable alternative especially in implementations having
30   high requirements for the accuracy of the transmission rate estimation.

It is also noted herein that while the above describes exemplifying embodiments of the invention, there are several

variations and modifications which may be made to the
disclosed solution without departing from the scope of the
present invention as defined in the appended claims.

CLAIMS

1. A method for estimating data transmission rate in a
communication system with variable data transmission rates
5      wherein a transmission signal includes a plurality of data
symbols over a sequence of data frames, comprising:
        classifying a data frame of a received transmission
signal in accordance with a predefined classification of the
data transmission rates; and
10       estimating the data transmission rate of the received
data frame on basis of said classification.

2. A method according to claim 1, wherein the classification
is based on frequency content of the received transmission
15     signal.

3. A method according to claim 1 or 2, wherein the
classification is based on a power spectral density function
estimate of the received transmission signal.
20

4. A method according to claim 3, wherein the power spectral
density function estimate of the received transmission signal
is calculated using a Fast Fourier Transform algorithm and
coherent averaging of the data symbol sequence of the
25     received transmission signal.

5. A method according to claim 4, wherein a modified Fast
Fourier Transform algorithm is used, said modified Fast
Fourier Transform algorithm taking predefined symmetries of
30     the transmitted data symbols into account.

6. A method according to any of claims 3 to 5, wherein the
estimation of the power spectral density function comprises
the steps of:

dividing the total number of received data symbols into blocks, wherein each block includes a predefined amount of consecutive points of the signal;

calculating an individual Fourier Transform for each of

5  said blocks for receiving squared real and imaginary points for each frequency of the signal;

calculating an individual power spectral function estimate for each of the blocks by summing the squared real and imaginary points; and

10  calculating the power spectral density function estimate by averaging the individual power spectral function estimates.

7.  A method according to any of claims 3 to 6, wherein the

15  power spectral density function estimate is normalised by summing the elements of the power spectral density function for obtaining a sum of the elements and by dividing each of said elements by the sum.

20  8.  A method according to any of the preceding claims, wherein the classification further comprises a step of removing effects of noise.

9.  A method according to claim 8 when taken together with

25  any of claims 3 to 6, wherein the noise removal comprises subtracting an inverse of the number of elements of the power spectral density function from the power spectral density function.

30  10. A method according to any of claims 3 to 9, wherein the classification comprises further:

calculating a variable from the power spectral density function for characterising the frequency content of the power spectral density function; and

comparing the variable against limit values of a
classification decision structure.

11. A method according to claim 10, wherein the variable
characterising the frequency content of the received
transmission signal comprises center-of-moment of the power
spectral density function.

12. A method according to claim 10 or 11, wherein the
magnitude of the variable indicates the relative amount of
high frequencies present in the power spectral density
function.

13. A method according to any preceding claims, wherein the
communication system comprises a cellular code division
multiple access communications network, and the data is
transmitted between a mobile station and a base station of
the network over a radio interface.

14. A method according to any preceding claims, wherein the
number of data transmission rate classes of the predefined
classification equals the number of the possible data
transmission rates.

15. A method according to any of claims 1 to 13, wherein the
number of data transmission rate classes of the predefined
classification is lower than the number of the possible data
transmission rates.

16. A method for channel estimation in a cellular code
division multiple access communication system wherein the
data transmission rate is estimated in accordance with any of
claims 1 to 15.

17. A method according to claim 16, wherein the estimate of the data transmission rate is used to assist in rate selection for Viterbi decoding of the received data symbols.

5    18. A method according to claim 16 or 17, wherein a data rate information received from a transmitting station and the estimated data transmission rate are both used for the channel estimation.

10   19. Signal receiving circuitry for use in a communication system with variable data transmission rates wherein data is transmitted as a plurality of data symbols over a sequence of data frames, the signal receiving circuitry comprising a rate estimation unit for receiving an incoming transmission
15   signal, for classifying a data frame of the signal in accordance with a predefined classification of the data transmission rates, and for determining from the results of the classification an estimate of the data transmission rate of the received data frame.
20

20. Signal receiving circuitry according to claim 19, wherein the rate estimation unit estimates the data transmission rate based on the frequency content of the received signal.

25   21. Signal receiving circuitry according to claim 19 or 20, wherein the rate estimation unit is arranged to classify the received signal based on a power spectral density function estimate of the received transmission signal.

30   22. Signal receiving circuitry according to any of claims 19 to 21, comprising a channel estimation unit which utilises the estimated data transmission rate of the received signal in channel estimation.

23. A mobile station including signal receiving circuitry
according to any of claims 19 to 22.

24. A base station including signal receiving circuitry
5     according to any of claims 19 to 22.
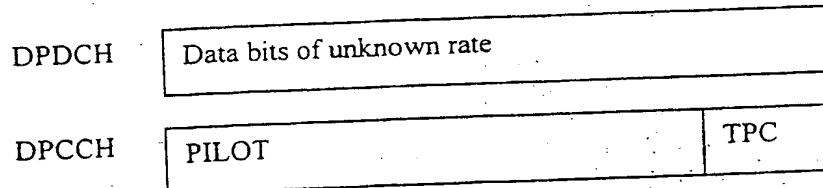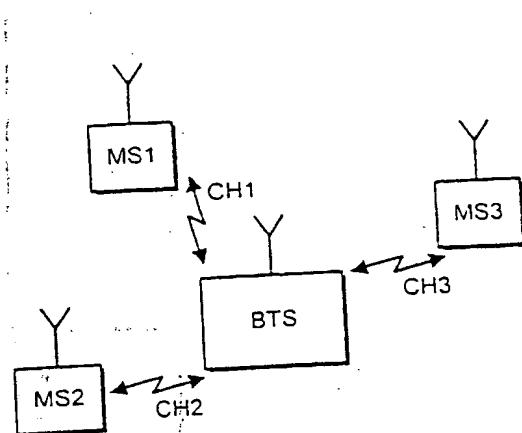
Fig. 1



| DPDCH | Data bits of unknown rate | |
|---|---|---|

| DPCCH | PILOT | TPC |
|---|---|---|

Fig. 3

FIG. 2

calculate PSD from these 64 received symbols

calculate PSD from these 64 received symbols

calculate PSD from these 64 received symbols

· · ·

calculate PSD from these 64 received symbols

32 values in PSD

32 values in PSD

32 values in PSD

· · ·

32 values in PSD

coherent averaging of 160 PSDs

bias = 1/32

remove the bias and reset negative values

$y(i)$

calculate the Center-of-Moment (CM)

$$cm = \frac{\sum_{i=0}^{31} i \cdot y(i)}{\sum_{i=0}^{31} y(i)}$$

decide transmission bit rate based on $cm$
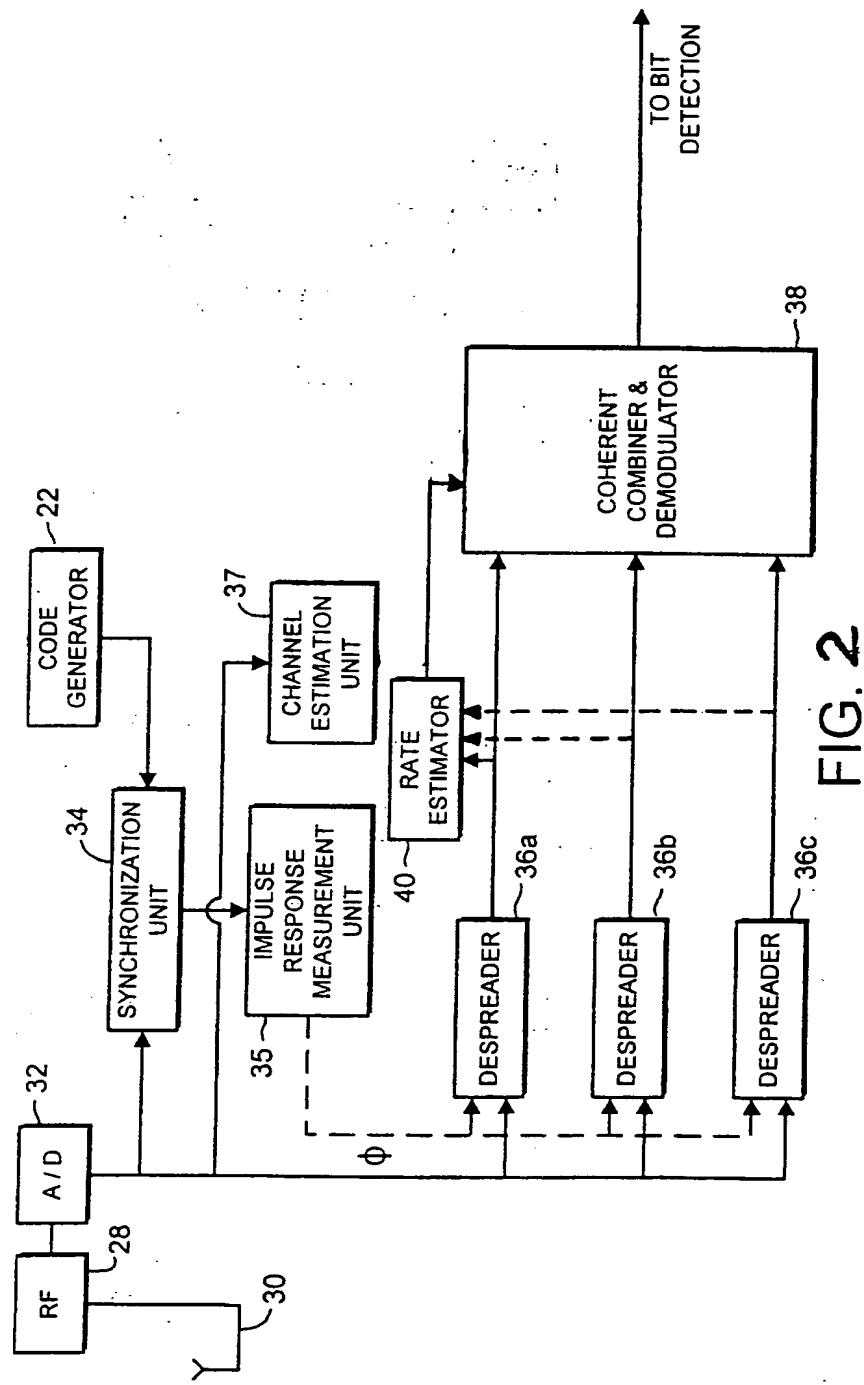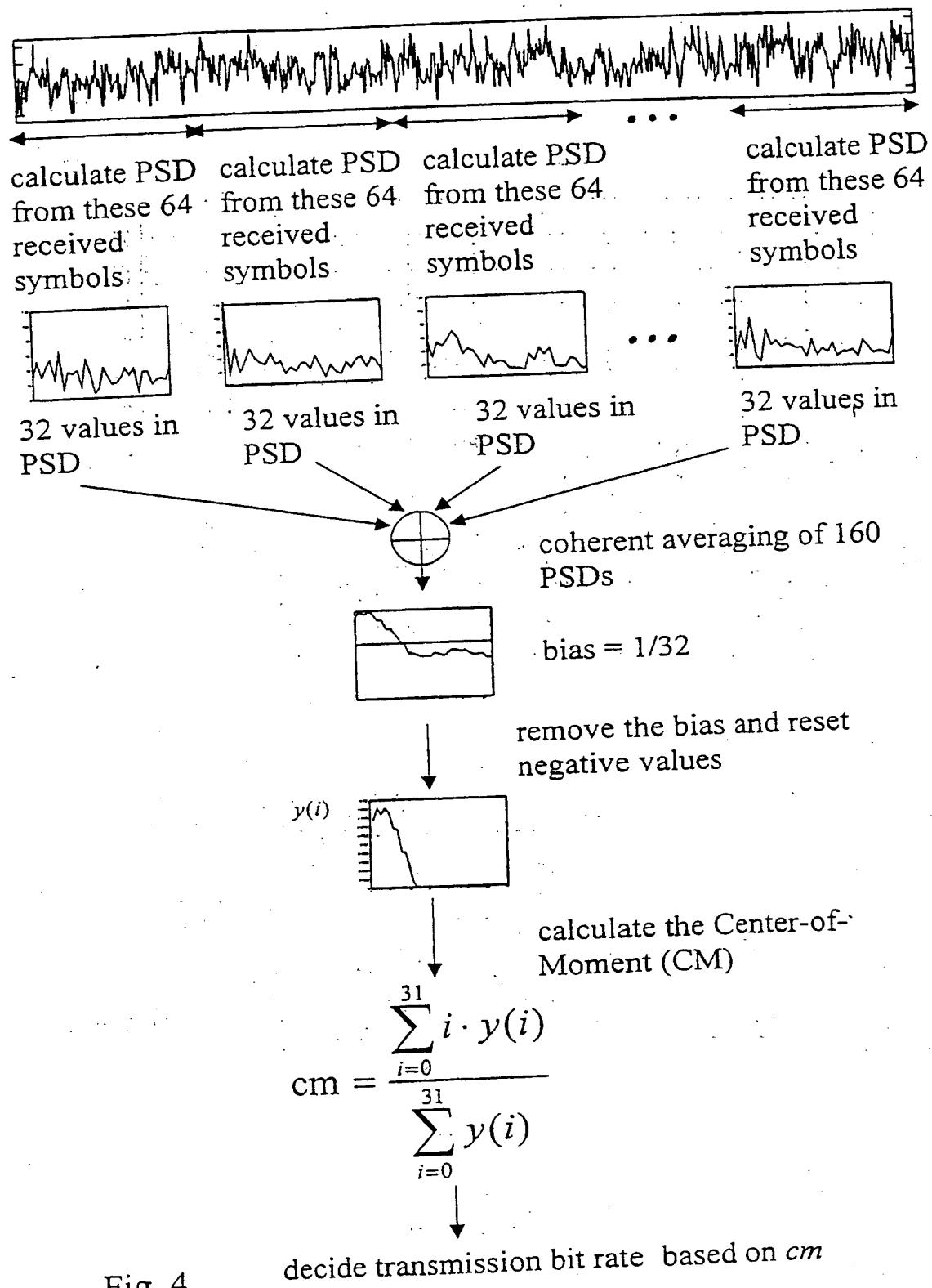
Fig. 4
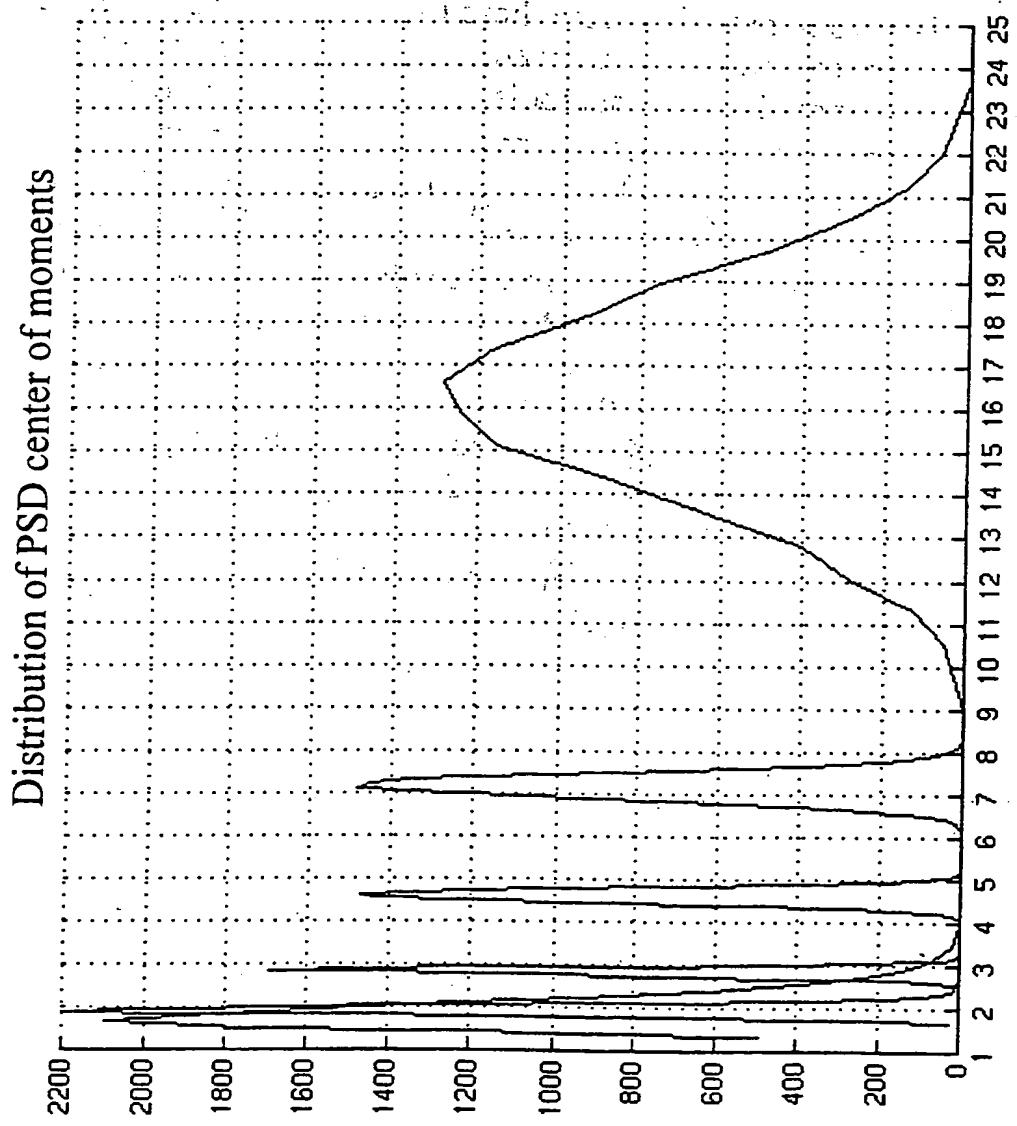
Fig. 5

# INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC 7    H04L25/02

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 7    H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | GB 2 301 999 A (OKI ELECTRIC) 18 December 1996 (1996-12-18)<br><br>page 3, paragraph 2<br>page 8, paragraph 2<br>page 13, paragraph 1<br>page 13, paragraph 3<br><br><center>-/--</center> | 1-3, 7-10, 12-24 |

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 12 May 2000 | 19/05/2000 |

| Name and mailing address of the ISA<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Authorized officer<br><br>Scriven, P |

Inter.. .onal Application No

PCT/EP 99/06719

**C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication,where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | SEOK HO KIM, SCHOLZ: "An optimum generalized cross-spectrum symbol-rate detector" IEEE TRANSACTIONS ON COMMUNICATIONS, vol. 41, no. 9, September 1993 (1993-09), pages 1399-1411, XP000396699 NEW YORK, US ISSN: 0090-6778 page 1399, right-hand column, paragraph 1 page 1399, right-hand column, paragraph 4 -page 1400, left-hand column, paragraph 1 | 1-3,8-24 |
| X | LEE ET AL.: "On a timing recovery technique for a variable symbol rate signal" IEEE VEHICULAR TECHNOLOGY CONFERENCE, 4 - 7 May 1997, pages 1724-1728, XP000738658 New York, US ISBN: 0-7803-3660-7 page 1724, right-hand column, paragraph 2 figure 5 | 1-3,7,8, 10,12-24 |
| X | US 4 887 280 A (REISENFELD) 12 December 1989 (1989-12-12) column 1, line 45 - line 51 column 4, line 21 - line 40 | 1-3,7,8, 10,12-24 |
| E | EP 0 944 212 A (MATSUSHITA GRAPHIC COMMUNICATION SYSTEMS) 22 September 1999 (1999-09-22) figure 4 | 1-3,7,8, 10,12-24 |

DCID: <WO    0119043A1 I >

# INTERNATIONAL SEARCH REPORT

Information on patent family members

| Patent document cited in search report | | Publication date | Patent family member(s) | | Publication date |
|---|---|---|---|---|---|
| GB 2301999 | A | 18-12-1996 | CA | 2183938 A | 24-02-1997 |
| | | | HK | 1001939 A | 17-07-1998 |
| | | | JP | 9172428 A | 30-06-1997 |
| | | | US | 5978428 A | 02-11-1999 |
| US 4887280 | A | 12-12-1989 | NONE | | |
| EP 0944212 | A | 22-09-1999 | JP | 11261785 A | 24-09-1999 |

THIS PAGE BLANK (USPTO)